Improvement of Fabrication errors for a High NA Microlens with Two Substrates

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Abstract:

A fabrication method of high numerical aperture(NA) microlens with two substrates is proposed. To satisfy the tolerance of surface spacing, accuracy of polishing process is improved by using flat dummy substrate. The surface spacing error of fabricated the high NA microlens is less than 3 μm.

A method to combine an aperture and the high NA microlens is also proposed.

Introduction

The microlens is mainly used in CCD and LCD projector to increase the efficiency of light. Recently, microlens is one of the most important components in optical communication[5] and optical data storage system[6]. The demands of microlens in these applications are high NA and easy-to-combination with other elements.

There has been a great deal of interest in the area of microlens fabrication. Various fabrication methods are reported, for example, ion exchange[1], thermal reflowing of photoresist pattern[2, 3], and dropping a resin by inkjet head[4], etc.

We proposed a novel structure of the high NA microlens that has three surfaces and two substrates. And possibility of fabricating the high NA microlens was shown[7].

In this paper, we improve the accuracy of surface spacing to introduce new wafer assemble process and fabricate an aperture on the high NA microlens surface.

Fabrication

The structure of the high NA microlens is shown in Figure 1.

Optical design software is used to design the structure of high NA microlens and calculate the target tolerance for fabrication process. The tolerance is calculated in the limitation of wavefront aberration 0.07 λ.

A diameter of this lens is 200 μm and NA is 0.85. Overall length is 708 μm. The high NA microlens consists of three lenses. L 1 and L 2 are convex lenses. L 3 is a concave lens and filled with a high refractive index resin. Materials of substrates and cover glass are fused quartz (n_D=1.45847). Refractive index of the resin filled with L3 is 1.620.

The tolerances of each surface spacing and optical axis displacement are ±3μm and ±1μm, respectively.

We proposed this high NA microlens and fabrication method before[7], and tried to make the High NA microlens. But surface spacing is larger than the tolerances. The surface spacing error was mainly caused by roughness of substrate S1 surface. So we modified the order of process and used a flat dummy substrate to improve the accuracy of surface spacing.

The modified process flow is shown in Figure 2.

The high NA microlens is fabricated with wafer assembling process. The photoresist replicas of microlenses L1, L2, L3 are formed by photolithography and transferred into fused quartz substrate by dry etching.

Surface spacing is adjusted by polishing and/or dry etching. Before this modification of process flow, we polished substrate S2 after bonding S1 and S2. At the polishing process, thickness of substrate S2 was measured as distance of upper S1 surface to upper S2 surface. Therefore, the measurement result was influenced by S1 surface condition. To reduce the thickness error of substrate S2, we polish the substrate S2 on the flat dummy substrate and bond S1 and S2 after polishing S2.

Two substrates S1, S2 and cover glass are bonded with UV hardening resin. When putting substrates S1 on S2, some errors are induced by shrinkage of resin. So the substrates are pressed strongly not to move after optical axis alignment, and resin are spread from a gap of substrates with capillary phenomenon.

And we add an aperture to the high NA microlens. Aperture is made with Cr thin film before fabricating the high NA microlens. The Cr film is sputtered and formed aperture shape by photolithography and wet etching.

Results and discussion

Surface spacing errors of high NA microlens are shown in Table 1.

Three-dimensional shape measuring instruments and measuring microscope were used for these measurement.

By a modification of a process, almost all items satisfied the tolerances ±3μm besides the cover glass thickness. The error of thickness of the cover glass was over the tolerance, 7μm. The cover glass was polished after putting S1 on S2. The cover glass thickness measured during polishing turned the S2 surface into a reference level. The surface of S2 was etched in 35μm deep and has roughness around 10%, 3.5μm.

To reduce the error, improving the uniformity of dry etching, or protecting the thickness measurement position not to be etched is needed.

Optical axis displacement are shown in Table 2.

Measuring microscope was used for this measurement.

Errors in X direction were under measurement limit. But Errors in Y direction were over 2.4 μm. The cause of errors in Y direction is a tilt of optical alignment system to Y direction. As shown in errors of X direction, revising a tilt of optical alignment system will reduce errors of Y direction.

A photograph of a fabricated high NA microlens is shown in Figure 3.

In the cover glass side view, the microlens is at the center. And other elements are spacers. Spacers control L1- L2 surface spacing and prevent inflow of resin into surroundings of lenses.

A white square area in the aperture side view is Cr film. And circle area at center of Cr film is aperture. The surface at aperture side was absolutely flat. So the addition of aperture to the high NA microlens was easy.

Conclusion

By the modification of process flow, we reduced the surface spacing errors except thickness of cover glass. Improvement of dry etching uniformity or protecting the measurement position will reduce the cover glass thickness errors.

We obtained the high NA microlens with aperture. The high NA microlens is easily combined with other optical elements.

References

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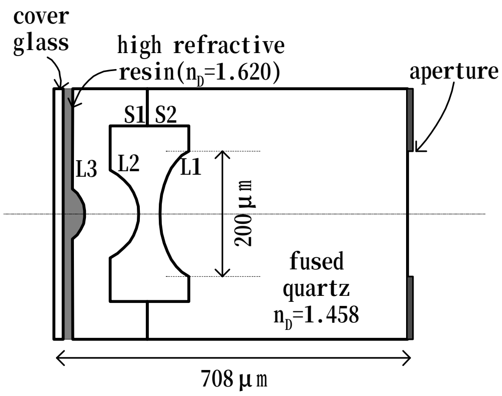


Fig.1 structure of high NA microlens

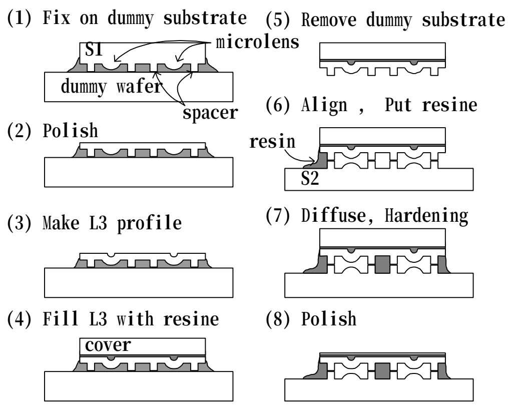
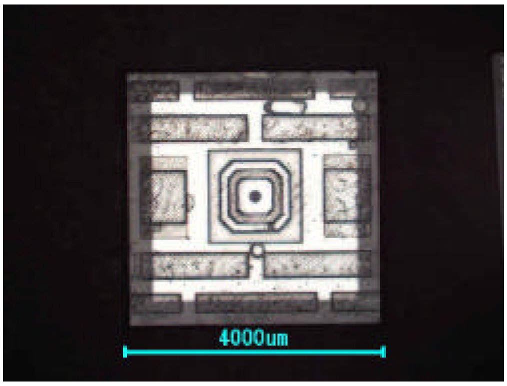
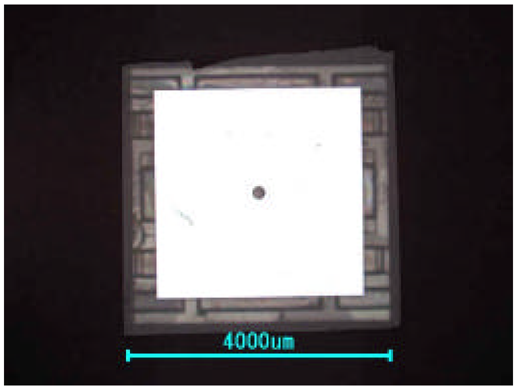


Fig.2 process flow



Cover glass side view



aperture side view

Fig.3 photograph of high NA microlens

Table 1 surface spacing error

Item	Process	Error (μm)
L1 height	Etching	-2.5
L2 height	Etching	+2.5
L1-L2 spacing	Etching Bonding	+2.6
S1 thickness	Polishing	-1.8
L3 height	Etching	+0.6
Cover glass thickness	Polishing Bonding	+7.0

Table 2 optical axis displacement from L1

	Axis displacement (μm)	
	X*)	Y
Aperture	0	+4.7
L2	0	+2.4
L3	0	+4.7

*) X-direction value is under measurement limit, <1μm.